HAZARDOUS WASTE REMEDIATION AND THE US ARMY CORPS OF ENGINEERS: FACILITATING TECHNOLOGICAL INNOVATION THROUGH CONSTRUCTION MANAGEMENT

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ABSTRACT

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Submitted to the Department of Civil Engineering on May , 1991 in partial fulfillment of the requirements for the Degree of Master of Science in Civil Engineering.

In the wake of our Nation's new found environmental morality, a potentially high-tech segment of the construction industry has emerged. **Hazardous Waste Management** is attracting firms and professionals with greater and greater momentum, as the numbers of government regulations, toxic wastes, and cleanup dollars all continue to grow. However, without proper strategic federal policies, this infant market segment may go the way of America's electronics and semiconductor industries: invasion and destruction by foreign competition.

As keepers of the earth, we must accept our responsibility for holding open windows of opportunity for future generations. As Americans, we can accomplish this most effectively by focusing our economic and social institutions towards developing and maintaining increased global competitiveness. Critical in this pursuit is a strong, domestic technology and contractor base from which increasing numbers of innovative environmental solutions will spring. However, our present litigious society, though effective in supporting the concept of an intergenerational social contract, impedes the innovation and entrepreneurial spirit so necessary for such development. To encourage the formulation of new and better technologies, we must subsidize innovation in this critical industry segment to attenuate the risks of future liability. The U. S. Army Corps of Engineers (the Corps) is an ideal vehicle for such a proposition.

Remediation of hazardous chemical wastes and disposal of nuclear spent fuels are inherently uncertain propositions. Private investment in any one of these endeavors would be at considerable cost and require substantial short-term returns on investment. Exposure to potential litigation makes such

ventures nearly impossible, both for smaller firms attempting to penetrate the market with innovative products or processes and larger firms with "deep pockets". Without some sort of subsidy, the market will tend to force new players from the scene, implicitly promote more conservative technologies, and encourage overall inefficiency. It is here the Corps can serve as a *test bed* or *incubator* for technological innovation and privatization of remediation programs. Using alternative procurement mechanisms, such as design-build or other turnkey approaches, market risks can be reduced. The Corps can also pursue traditional competitively bid contracts for innovative projects, but hold contractors liable only to the limits of the contract, not to the standards of processes yet to be developed. In this way, contractors are *de facto* indemnified if a new remediation technology is a loser; the Corps assumes the *ex post facto* risks of that technological failure. Therefore, the technology is at risk, not the contractor. Such a method delivers the needed subsidy in the form of risk attenuation resulting in correspondingly lower costs of capital, bid bonding, and performance insurance. Overall contract costs are lower with, in the case of alternative procurement mechanisms, constructability and biddability engineered directly into the design making the final product more technically and financially sound. Innovative technologies for hazardous waste remediation brought more quickly to the market, at a lower cost, provide more and better information for our national policy-makers and scientists. Our technology base is strengthened, thereby increasing our Nation's competitiveness abroad, allowing us a better hold on our commitment to the environment and future generations.

This thesis is a call for employing the U. S. Army Corps of Engineers as facilitator of innovative hazardous waste remediation technologies and construction management programs. My central thought is that these technologies and management programs, once developed in a relatively low risk environment at military installations, would be transferred directly to the private sector for cleanup of Superfund and RCRA sites. As a result, our technology and construction contractor bases would be strengthened, bolstering our Nation's competitiveness in this burgeoning global industry.

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This thesis is the result of much hard work and dedicated thought over the last fifteen (15) months. During that time, I have had to rely on the assistance and understanding of many people who rightfully share in the completion of this manuscript. I would like to briefly thank some of them, here, and hope that I have justified their trust and support with the quality of the pages that follow.

My wife, Marion, whose love and inspiration kept me true to the task at hand; my Dad, whose lifelong encouragement and example brought me to think I could even be accepted at MIT; my Mom, who watches over and guides me from God's kingdom in Heaven; and Professor Moavenzadeh, my thesis advisor and academic mentor, whose wisdom and patience have guided my every step along the way.

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For Mom and Dad

Chapter 1

INTRODUCTION

In the past several decades, Americans have significantly changed their view of the world around them. Industrial pollution and hazardous wastes are now the guidons for a more informed and engaged public environmental awareness. Government and industry are being pressured towards a more enlightened stewardship of our national resources: the former, to promulgate and enforce regulations; the latter, to develop more environmentally-benign products and processes. Industry's *Corporate Veil* and the Government's *Veil of National Security* are being pierced. As a result, both have committed considerable time and money towards satisfying the environmental demands of their customers and constituents.

In the wake of this new found public morality, a potentially high-tech segment of the construction industry has emerged. **Hazardous Waste Management** is attracting firms and professionals with greater and greater momentum, as the numbers of government regulations, toxic wastes, and cleanup dollars all continue to grow. However, without proper strategic federal policies, this infant market segment may go the way of America's electronics and semiconductor industries: invasion and destruction by foreign competition.[1]

As keepers of the earth, we must also accept our responsibility for holding open windows of opportunity for future generations. As Americans, we can accomplish this most effectively by focusing our economic and social institutions towards developing and maintaining increased global competitiveness. Critical

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[1] Strategic issues for both of these industries are presented in *Technology and Competitiveness: The New Policy Frontier* by B. R. Inman and Daniel F. Burton, Jr., **Foreign Affairs**, Spring 1990, 116-134.

in this pursuit is a strong, domestic technology and contractor base from which increasing numbers of innovative environmental solutions will spring. However, our present litigious society, though effective in supporting the concept of an intergenerational social contract, impedes the innovation and entrepreneurial spirit so necessary for such development. To encourage the formulation of new and better technologies, we must subsidize innovation in this critical industry segment to attenuate the risks of future liability. The U. S. Army Corps of Engineers (the Corps) is an ideal vehicle for such a proposition.

The U. S. Army Corps of Engineers has a distinct responsibility and unique aptitude to assume the lead in resolving our environmental dilemmas. As the Nation's Engineer, the Corps is capable of providing, at the least, technically and scientifically feasible alternatives. This is not just wishful thinking, however. With over a century of experience, the Corps has forged strong relationships with society and industry, speaking highly for its role as intermediary and coordinator in what will surely be environmental dispute resolution rather than the simple application of technology. In addition, the Corps is a stable, government organization capable of bearing significant financial and operating risk. If for no other reason than this, the Corps is an ideal mechanism for technological insurance underwriting and information gathering at significantly reduced costs. Both the opportunity costs of inaction and those of ill-advised policies based on insufficient study can be mitigated.

Achieving goals means applying science to situations the best way we know - in other words, taking risks.[2] The Corps' capacity to assume considerable risk in developing solutions for our unique environmental problems is particularly noteworthy. Remediation of hazardous chemical wastes and disposal of nuclear spent fuels are inherently uncertain propositions. Private investment in any one of these endeavors would be at considerable cost and require substantial short-term returns on investment. Exposure to potential litigation makes such ventures nearly impossible, both for smaller firms attempting to penetrate the market with

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[2] Robertson, William L. *To Be Environmental Engineers For The Nation*. (Strategic Working Paper #89-3, 11 April 1989), 4.

innovative products or processes and larger firms with *deep pockets*. Without some sort of subsidy, the market will tend to force new players from the scene, implicitly promote more conservative technologies, and encourage overall inefficiency. It is here the Corps can serve as a test bed or incubator for technological innovation and privatization of the remediation process. Using alternative procurement mechanisms, such as design-build or other turnkey approaches, market risks can be reduced. The Corps can also pursue traditional competitively bid contracts for innovative projects, but hold contractors liable only to the limits of the contract, not to the standards of processes yet to be developed. In this way, contractors are de facto indemnified if a new remediation technology is a loser; the Corps assumes the ex post facto risks of that technological failure. Therefore, the technology is at risk, not the contractor. Such a method delivers the needed subsidy in the form of risk attenuation resulting in correspondingly lower costs of capital, bid bonding, and performance insurance. Overall contract costs are lower with, in the case of alternative procurement mechanisms, constructability and biddability engineered directly into the design making the final product more technically and financially sound. Innovative technologies for hazardous waste remediation brought more quickly to the market, at a lower cost, provide more and better information for our national policy-makers and scientists. Our technology base is strengthened, thereby increasing our Nation's competitiveness abroad, allowing us a better hold on our commitment to the environment and future generations.

Engineering skills and tools are abundant within the Corps at its thirteen (13) engineering divisions and thirty-nine (39) districts worldwide, and at its three (3) central laboratories. The synergy of using all of these to facilitate the development of new and better remediation technologies and construction management programs, is clear. In fact, the Corps is already an active player in this process, working with the Environmental Protection Agency (EPA) to such ends. The Hazardous Waste Research and Development Center (HWRDC) at the Waterways Experiment Station (WES) in Vicksburg, Mississippi (one of the Corps' central labs) is active in developing new advanced treatment technologies and new testing protocols for contaminated materials and has been designated an EPA Center for Best Demonstrated Available Technology program evaluation under the Resource Conservation and Recovery Act (RCRA). WES also provides R&D services under the Superfund (CERCLA) program and the Clean Water Act.

Above and beyond these wealth of attributes is the fact that the Corps is an agent of our government and our national policy. It has its *finger on the pulse* of national sentiment and our policy-makers' desires, along with understanding its greater task of maintaining the Nation's trust. The Corps is central in coordinating the engineering solutions to our environmental problems and presenting them to our Nation. Hopefully, our national civilian leadership recognizes this and will utilize the Corps' strengths to a greater degree in the future - for the future.

This thesis is a call for employing the U. S. Army Corps of Engineers as facilitator of innovative hazardous waste remediation technologies and construction management programs. My central thought is that these technologies and management programs, once developed in a relatively low risk environment at military installations, would be transferred directly to the private sector for cleanup of Superfund and RCRA sites. As a result, our technology and construction contractor bases would be strengthened, bolstering our Nation's competitiveness in this burgeoning global industry.

In support of these points, my thesis is arranged in the following way:

Chapter 2: ***A Model*** defines the underlying situation and decision environment, introducing the **Society-Government-Industry Triad** and the relationships between its "key players". The concepts of moral responsibility, global competitiveness, national security, and an alternative valuation framework are introduced.

Chapter 3: ***Arguments and Issues*** specifically addresses the concepts introduced briefly in Chapter 1.

Chapter 4: ***Risks*** discusses our nation's military toxic legacy, to include the magnitude of the problem, the type of toxics, and their environmental impacts. The intent is to highlight the similarities between military and civilian contaminants and to show that technologies and programs developed at Defense Department sites are easily applied at their civilian counterparts.

Chapter 5: ***Responsibility*** presents the Defense Environmental Restoration Program (DERP) and assesses its effectiveness. The intent is to understand how military cleanups are now effected and the problems associated therewith, hopefully to steer clear of the same miscues in the future.

Chapter 6: ***Technical Alternatives*** offers a range of technical solutions for use at contaminated sites, both military and civilian. Developing treatment trains with these technologies to apply at specific contaminants and specific sites is also discussed.

Chapter 7: ***Strategic Market Analysis*** presents an analysis of the hazardous waste management segment of the construction industry using the models developed by Porter in **Competitive Strategy** and **Competitive Advantage**. The concept of employing the Corps as a *test bed* or *incubator* for new remediation technologies and construction management programs is introduced.

Chapter 8: ***The U. S. Army Corps of Engineers*** is the concise statement of why the Corps should be employed as facilitator of innovative remediation technologies and construction management programs. It synthesizes the preceding discussions and restates the central thought of the thesis.

Chapter 9: ***Conclusions and Recommendations*** presents the *lessons learned* from my research and analysis, focusing specifically on our military environmental programs as a vehicle for the Corps as facilitator of private sector development.

Chapter 10: ***Further Research Required*** offers several topics which are of specific importance to furthering the effectiveness of the Corps as our Nation's engineers and the world's largest construction management organization.

Chapter 2

A MODEL

This chapter begins the discussion of hazardous waste site remediation by looking at the underlying decision environment. This is presented in the form of the Society-Government-Industry Triad. In defining the interrelationships and interactions between the "key players", a more global appreciation of our toxic legacy can be developed. The concepts of moral responsibility, global competitiveness, national security, and an alternative evaluation framework are also discussed in this light.

Before one attempts to understand the problems, and to ultimately develop solutions, the decision environment first be defined. This definition centers around the **Society-Government-Industry Triad** (Figure 1) and the relationships between the "key players". These relationships can be briefly described as follows: The Environment, as host to our endeavors, provides Industry with natural resources and Society with other benefits, in the form of clean air to breathe, clean water to drink, and clean land on which to live. Societal awareness of its impact on the environment initiates the reform process which influences 1) Government toward law and public policy and 2) Industry toward more environmentally-benign products and services. In response, theoretically, Government promulgates laws and regulations while Industry develops 1) improved production processes and alternative raw materials, and 2) cleaner products. Because this translates into additional financial and operating expenses, however, Industry's anti-environmental lobbying efforts are directed toward mitigating the consequences of these new constraints. Society then, hopefully, adjusts its behavior, either voluntarily or through mandate, to reduce pollution and conserve energy. Government directly destroys the Environment through its military operations while providing for the national defense. The environmental opportunity costs of inaction and the detrimental effects of poor policy decisions forced by political pressure also directly affect the Environment. Governmental influence toward positive environmental change is also realized through the actions of Industry and Society.

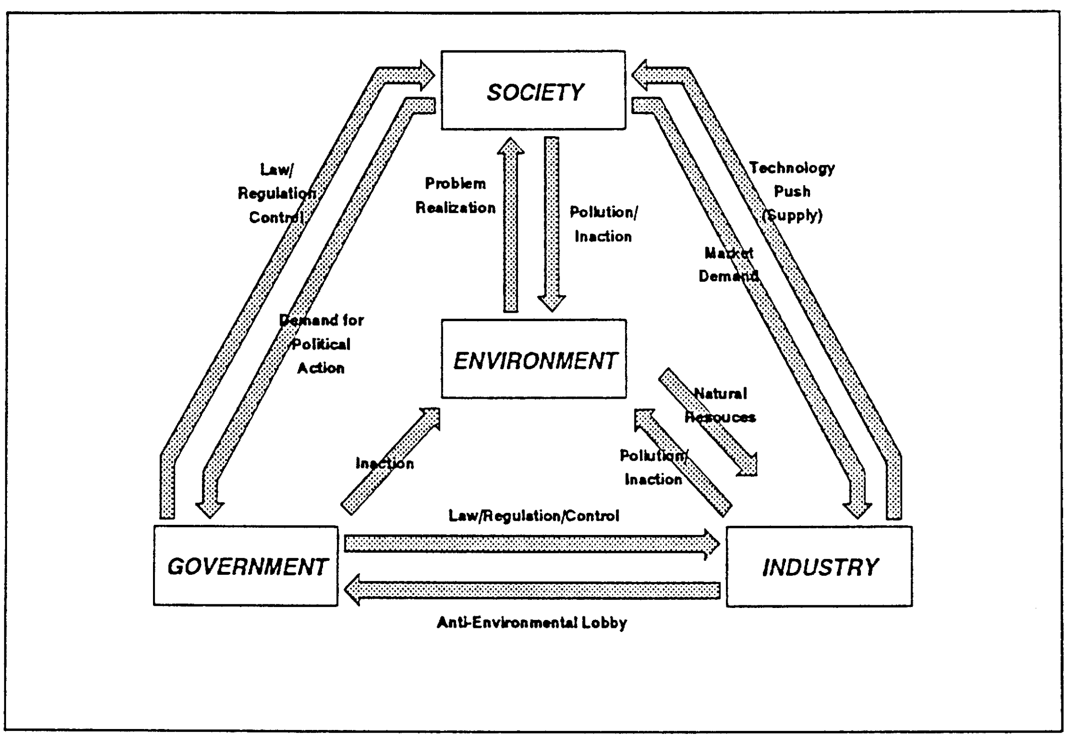

Figure 2-1. SOCIETY - GOVERNMENT - INDUSTRY Triad.

Long term, intergenerational environmental concerns fall into two general categories: depletion of natural resources and pollution. First, our presence on the planet is depleting its limited natural resource base which, once gone, is not available to our offspring. Second, through our processing of these resources, we are polluting the planet, in some instances with toxic chemicals and radioactive wastes, which impose both health and cleanup costs on the future. In both cases, the future standard of living may be significantly lowered and accidental deaths may result.

A more general problem is understanding the interconnectivity of activities and events now, and over time. For example, energy policy shapes pollution and natural resource base depletion; the environment affects and determines which energy policies are feasible and attractive. Political issues of budget and re-election determine which policies are championed and administered which in turn affect monies for research and development of new technologies which define the range of feasible alternatives and their long term environmental effects. Most importantly, however, is the understanding that logical and analytical technology fixes only create the feasible region of solutions from which policy-makers will choose; the resolution is political and interpersonal rather than technical. However, this does not relieve the engineer or scientist from pursuing a technical panacea. On the contrary, it is this pursuit which plays an important role in the overall solution. This pursuit, itself, breeds yet another problem of note. However, whether it be for financial benefit or professional recognition, introducing new technology, especially in the production process, often does not reflect the best engineering solution when one adopts the long term, more holistic environmental perspective. The optimal engineering solution not only balances available resources, but is also the most conservationist. That we have developed design and engineering methods which, in practice, are not the most efficient and environmentally-benign is possibly our worst legacy.

The Society-Government-Industry Triad presents a centerpiece for describing how the key players interact in the big environmental picture and forms a framework for addressing critical questions of moral responsibility and public policy. However, the analysis of our long term moral responsibility must be grounded in reality and in the present. Before answers can be developed, a valuation framework for alternatives must be established, both for future and present generations. Questions of national security and industrial competitiveness must be considered, as well as decision-making with imperfect information and how decision-makers value the possible outcomes, assuming they know what they are.

The specific problems facing the federal government and the U S Army Corps of Engineers are 1) how to mitigate the long term, intergenerational environmental effects of our inhabiting this planet (Total Waste Management) and 2) how to repair the damages of our past environmental sins (Hazardous Waste Remediation). Furthermore, how can the Corps be empowered to reconcile conflicting environmental goals, imperfect markets, and the rights of souls yet unborn with technological development and U S global competitiveness for effecting dynamic environmental reform.

In the next chapter, the arguments and issues introduced here will be discussed. Specifically, moral responsibility, global competitiveness, national security, and an alternative valuation framework are presented.

Chapter 3

ARGUMENTS and ISSUES

In this chapter, the issues and arguments introduced in Chapter 2 will be explored more deeply. Specifically, moral responsibility, global competitiveness, national security, and an alternative valuation framework for environmental decisions are discussed. The intent of this presentation is to highlight the urgency of our national toxic legacy and the need for action in its remedy.

MORAL RESPONSIBILITY

The three (3) most forceful arguments for describing our intergenerational moral responsibility for the environment are 1) equal opportunity for future generations, 2) the identity of future generations, and 3) the idea of an intergenerational social contract. The argument of **equal opportunity** states that all persons, including those not yet born, have the moral right to an equal opportunity for self-determination and for pursuing their own self-interests. **Identity** underscores the proposition that our actions, and inactions, will determine the identity of persons in the future. Finally, the **social contract** champions the idea of intergenerational moral (and fiduciary) responsibility.

At the center of the discussion are the questions: Should we consider future generations at all? and Do we, in fact, have a moral responsibility for the effects of our present actions on the future? In general, the consensus is that we, collectively, do have a responsibility to our descendants to preserve the earth for their future personal benefit. So develops the idea of an intergenerational, social contract in which we are liable to the future for our actions. What makes this proposition so practically awkward, however, is that "future generations have no way of enforcing a fair deal on present ones."[3] Therefore, we apparently enjoy a "free lunch", as we will never feel the long term consequences of our actions. But, there are no "free lunches". In fact, the prescripts of common law and social responsibility dictate a justice between peoples, whether across political boundaries or across time. The doctrine of *ex post facto* is now being coupled with *joint and several liability* to bring responsible parties to justice for their past environmental sins. Though some of these parties are not specifically responsible for many of the sites and are pursued only on the basis of their asset value ("deep pockets"), the principles of moral responsibility and the social contract remain. The strength of these concepts is not a matter of conjecture. American industry is moving increasingly toward Total Hazardous Waste Management with on-site treatment and away from remedi-

[3] Peter G. Brown and Douglas MacLean, ed., **Energy and the Future** (Totowa, New Jersey: Rowman and Littlefield, 1983), 25.

ation and cleanup after the fact, primarily because of the fear of future litigation - a license for which the Judicial system has written our descendants.

The second argument embodies the proposition that our actions will dictate the social conditions in years hence and effectively determine the identity of future individuals. In addition, our chosen course of action (or inaction) will alter future worlds and determine who will be born; "different choices mean different people will exist."[4] As an academic or philosophical exercise, this argument has interesting permutations and possibilities. However, as a practical philosophy for policy and prudent individual conduct, it is lacking. The idea that people today should concern themselves with the limitless mixture of individuals who might never be born because we acted in one way or another is to be too fearful of the future. It is really not for us to say who will be conceived and who will not, nor should it be. The dynamism of the world will determine the identity of future souls to inhabit the planet. That is not to say that fate alone will

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[4] Brown and MacLean, 11.

guide the future, because it will not. We will have a great hand in determining which nations and societies survive and, therefore, we should actively attempt to shape our world and its possibilities. Nor is it to say that we, as citizens of the earth, have no responsibility for our world, because we do. Our lot is to build a peaceful, civilized, and responsible future for ourselves and our posterity, and in this way shape their identities. It has been our accomplishments to date that have brought the world from the stone ages (whether this is, in fact good is another argument) and which will propel us forward into centuries untold. It is also inevitable that the human race will grow in size, complexity and, we would hope, understanding. Our legacy should be as pathfinders of new and better ways to develop our world towards fostering the evolution of the human spirit. The worst lesson we could teach our children would be one of inaction and fear of possibilities unreal and unimagined.

The final argument concerns the right of all individuals to an equal opportunity for fulfilling their personal potential, across both interpersonal and time-space boundaries. Of import is the possibility that by depleting the earth's natural resources and destroying the environment, without developing remedial technologies and products, we decrease the opportunity for future generations to pursue their ends; "the more we use, the fewer options future generations will have, other things being equal".[5] This seems to be a very plausible and logical presentation of our otherwise debatable responsibilities to the future. If we accept our inability to choose the specific identities of the earth's future inhabitants and that our socio-economic institutions will change (adjust) to the dynamic forces of the world community, simply to survive, then the only expectation the future can have of us is that we act as proper stewards of the planet to leave open to them the same windows of opportunity left open to us by our forefathers. This introduces the question of whether our forefathers thought of our welfare in pursuing their own livelihoods. The answer is, as it should be for us, yes; it is imperative that we pass what we have learned and achieved to our offspring in a form which they can develop even further, as the past has done for us. Though perhaps not discussed in the

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[5] Brown and MacLean, 17.

same breath as the imperatives of environmental remediation, is the implicit understanding that we pass millennia of human development and achievement to the future, each and every day. The issues of environmental reform are certainly critical and if we are to leave open a window of equal opportunity for future generations, we must act now to make the present a better example of cooperation, understanding, and mutual responsibility.

U. S. GLOBAL COMPETITIVENESS AND NATIONAL SECURITY

Along with these philosophical foundations, the practical issue of our Nation's present competitiveness in international markets also must be considered. In this instance, we must consider the balance between technological development, resource depletion, and our domestic technology base, as well as how sacrificing today will impact on opportunities for the future.

The proposition that we have a distinct responsibility to maintain windows of opportunities open for our children, once accepted, focuses our attention on the need for strong economic and social institutions. Though these will change with the world around us, our responsibility to the future dictates the need for a stable environment of technological and scientific development. The way in which this can be accomplished is by maintaining a solid and dynamic technology base of contractors, entrepreneurs, and technicians along with a competitive environment in which new ideas and potential environmental solutions can be developed. In this way, market competitors, pursuing their own personal potentials and financial rewards, will develop and test the engineering skills and tools necessary to keep windows and their option spaces open. Today, however, this is not the case for many firms and competitors in our country. Fear of litigation, much like the fear of the future, impedes market processes and extinguishes the desires of the present and, along with it, the hopes for the future. In addition, because many firms decide not to compete based on litigation risks, technologies may be developed off-shore, that is, by foreign firms whose governments are more supportive of their technological endeavors (Japan, for

VALUATION FRAMEWORK

The practical presentation of our moral responsibility must be more than a hypothetical or academic exercise. It must be enunciated in financial and economic terms that it is in our own, present best interests to act more courageously and astutely as stewards of the earth. Inherent to such a presentation is a discussion of the discount rate and the utility of consequences, to account for the time value of money and the intensity of value of the outcomes. However, setting a discount rate or utility is personal, subjective, and time-situation dependent. Instead of conventional Net Present Value or Valuation by Components methods, perhaps the better presentation of issues such as comparing the costs and benefits of present and future generations is through understanding the utility of options and the alternatives generated for decision-makers.

The proper discount rate is a matter of conjecture even in the most concrete of short term cases. Risk adjusted assessments using the Capital Asset Pricing Model, for example, do not yield agreement or consensus. This is due to the personal and situational nature of risk and the utility of reward. Suffice it to say that for any situation and for every analyst, there are an equal number of methods and explanations for choosing a discount rate, none more accurate than the next. In the context of valuing the future consequences of our present actions, conventional tools, such as Net Present Value and Valuation by Components, are not particularly useful. This is because any consequence in a distant future period, no matter how valuable, will be worth next to nothing in present terms. To compound this problem, the present value is very dependent on the discount rate, already accepted as dubious and inaccurate at best. One has, then, a dilemma with which to deal: how to present a logical, financial case for the very significant and essential benefits of environmental and energy reform? That is, how to sell enlightened planetary stewardship to government and to the captains of industry? The answer lies, perhaps, in the understanding that there is value inherent in flexibility and in information; with more information or increased flexibility, the number of alternatives available to the decision-maker increases example). When, and if, this occurs, we lose our handle on the responsibility we have accepted. If we, in fact, seriously entertain a responsibility to our descendents, we must forcefully act to ensure they have the brightest of futures. This means devoting time and resources toward technologies which help us to contaminate less and conserve more. In doing so, we develop competitive advantage over other firms and nations of the world community who, perhaps, do not share our commitment. This means, in more practical terms, less dependence on foreign fossil fuel reserves. This in itself would open ever increasing numbers of political and economic alternatives and, most importantly, preserve the lives of our service members, much like those now serving in the Persian Gulf. We would also develop a stronger technology base, upon which economic and political force is founded. Our sacrifices for competitiveness would not, however, equate to reductions in the present standard of living. On the contrary, we would learn to conserve, and preserve, making us stronger and more competitive. The effect would be to create even more windows of opportunity for the present and the future.

and risks are reduced, thereby increasing the feasible region of opportunities and improving the optimal solution. Therefore, any activity which can either increase flexibility or provide more and better information, theoretically, has value. It follows, then, that environmental reform has value because it secures and perpetuates the decision environment, allows the decision-maker more time to gather information, and increases the number of technologies available for economic growth.

Along with presenting environmental stewardship in this valuation format, one must identify what the consequences to both future and present generations can be. This is an especially difficult task, as we cannot know the future nor the technologies then available, nor do we know the societal changes which will inevitably take place in the interim. Additionally, many of the impacts of pollution and resource depletion are presently invisible and will be discovered only with time and technological innovation. There are, however, adverse impacts which we do understand and it becomes our responsibility to deal with them as effectively as possible. This accepted, the practical complication arises when one considers the different key players presented in the Society-Government-Industry Triad (Figure 2-1), and their respective risk horizons and goals. It would be folly to assume that all of these institutions value environmental reform in the same fashion or to the same degree. There are different risks associated with each player in any proposed solution, just as there are different consequences. One solution to benefit Society may degrade the positions of Government and Industry, or may not be acceptable because the benefits are beyond their comprehension (in terms of time horizon for realizing the rewards). This understood, the question then becomes how to present a solution which will be mutually beneficial to all three?

The arguments and issues presented in this chapter enunciate the urgency with which we must act in remedying our lack of environmental consciousness. This is specifically relevant in the case of our nation's military toxic legacy, considering the higher moral standards to which the Nation's armed forces are expected to aspire. In the next chapter, this legacy will be addressed, to include its size, toxicity, and environmental impacts.

Chapter 4

RISK

With the possible exception of the Soviet military, the United States Armed Forces are arguably the most indiscriminate and irresponsible polluters on earth. In the name of national security, our armed forces deposit thousands of tons of hazardous materials into the environment each year, both on federally-owned reservations and private property. Much about these wastes, and the problems they cause, is already known. However, discovery of contaminated "hot spots" is not by any measure complete.

This chapter shifts emphasis from the general arguments and issues presented in Chapter 3 and examines the risks to society and the environment created by military toxics. Specifically, the magnitude of our military toxic legacy, the types of toxics generated by DOD, and the environmental impacts that result will be addressed.

MAGNITUDE OF THE PROBLEM

The Defense Department (DOD) is a major producer of hazardous waste. DOD generates over 400,000 tons each year from industrial processes, primarily used to repair and maintain weapons systems (F-16 Aircraft) and equipment (trucks). Data provided by the armed services show that in 1986 the Air Force, the Army, and the Navy generated about 96,000, 139,000, and 183,000 tons, respectively, of hazardous waste.[6]

[6] U. S. General Accounting Office, Report to Congressional Requesters, **Hazardous Waste: DOD Efforts to Reduce Waste**, GAO/NSIAD-89-35, February 1989, 2. These numbers agree with those provided by Michael Renner in *Assessing the Military's War on the Environment*, **State of the World 1991: A Worldwatch Institute Report on Progress Toward a Sustainable Society**, 143.

Virtually every military installation in the U. S., as well as numerous minor facilities and former bases, has caused extensive environmental damage. The known extent of DOD's toxic legacy (also) continues to grow. DOD owns 3,874 properties in the U. S. and its territories, including 871 major military installations. As of September 30, 1986, the Defense Department had identified 3,526 "potentially contaminated" sites at 529 locations. Five years later, the total now stands at over 17,000 sites at 1,579 locations.[7,8] Additionally, more than 1,200 public and private properties around the U. S. are currently on, or proposed for listing on the (EPA Superfund National Priorities List) or NPL.[9] The Pentagon is a Potentially Responsible

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[7] Lenny Seigel, Gary Cohen, and Ben Goldman, **The U. S. Military's Toxic Legacy: *America's Worst Environmental Enemy***, The National Toxics Campaign Fund (January 1991), 1-2.

[8] The original estimate provided in the National Toxics Campaign Fund report (January 1991) quoted a total of 14,401 "potentially contaminated" sites identified by the Defense Department. Since that report was published, the number has increased by approximately 3,000 in an annual DOD report to Congress. These more than 17,000 sites span the spectrum in size from entire firing ranges and production facilities to sites where only a few barrels of contaminants required disposal. (Source: *Contamination Report*, **Army** vol 41 no 5 (May 1991), 64. Published by the Association of the United States Army).

[9] Siegel, et al, 3-4.

Party (PRP) at 53 of the privately-owned NPL sites, including dumps, properties formerly owned by the military, and contractor-owned weapons plants.[10]

The number of facilities identified as having contamination problems is expected to level off soon, since the armed forces have surveyed most of their facilities.[11] This is a dubious assertion, however, as the discovery of new sites will continue to be a major task. Additionally, degradation of currently identified sites will continue to confound remediation, cleanup, and closure efforts as long as quick and decisive actions are delayed with procedural matters.

TYPE OF TOXICS

The Cold War's chemicals which permeate our environment include industrial solvents, paints and dyes, fuels and propellents, acids, pesticides, herbicides (containing dioxins), heavy metals, PCBs, photographic

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[10] Siegel, et al, 11.

[11] Siegel, et al, 3.

chemicals, refrigerants, asbestos, cyanide, and medical wastes ... nerve gas and unexploded artillery shells ... (and) combined radioactive and toxic wastes.[12]

The toxicity of most military hazardous wastes is not materially different from their civilian counterparts. In fact, there does not appear to be any evidence that the majority of military toxics pose a greater threat, chemically, than those found at private sites. It is secrecy and non-compliance with reporting requirements that cause dangers to human health and surrounding ecosystems when remediation efforts are confounded.

Military-specific wastes -- chemical munitions and unexploded ordnance -- do, however, pose special threats to the environment and public safety. Not only is there an immediate danger of explosion or lethal release during removal and remediation, further contamination through decomposition and leaching, much like heavy metals at industrial sites, is also a significant problem. This is especially true considering the size

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[12] Siegel, et al, 1.

and number of active and abandoned training installations where indirect fire (artillery shells) have impacted and remain unexploded.

ENVIRONMENTAL IMPACT

As with contaminants at civilian sites, inter-media migration is a concern at DOD locations. Groundwater contamination and volatilization of toxics are only two (2) of the many mechanisms which facilitate migration between environmental compartments and cause concern for stakeholders and policy-makers alike.[13] Military toxics, though not significantly different with regard to their migratory nature, also contaminate surrounding ecosystems beyond the borders of DOD installations.

Migration pathways of contaminants do not recognize the sanctity of political boundaries nor the limits of

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[13] *Compartment* refers to one (1) of six (6) parts of the environment within which toxics and contaminants can migrate and eventually contact humans. As a matter of reference, the compartments are 1) air, 2) water, 3) land, 4) suspended solids in water, 5) bottom sediment in water, and 6) biota. Understanding how military contaminants migrate between and within these compartments, based on chemical mass balances, will help to describe the dynamic and pervasive nature of the environmental problems that may arise.

military reservations. Not only are service members and their families at risk. Bordering communities and activities are also impacted when toxics contaminate drinking water supplies and the surrounding air. Considering the number and size of sites worldwide, that impact is substantial. However, it is only now beginning to be addressed by Pentagon officials.[14]

Remedial inaction also exacerbates environmental problems at military hazardous wastes sites. Not unlike their civilian counterparts, military cleanup efforts are delayed for numerous reasons, budget and "national security" the most noteworthy. These delays amplify the problems caused when contaminants migrate and spread by way of geologic and inter-compartmental pathways to neighboring population centers. The environmental opportunity costs of delayed responses are significant and speak for a revised approach, focused on action and remediation.

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[14] Siegel, et al. This report is replete with specific examples where military toxics have migrated off the installation and contaminated civilian communities. See pages 12, 14, 17, 28, 34, 43, 48, 57, 60, 75, and 80.

In this chapter, the magnitude of the military's toxic legacy was explored, as well as its environmental impacts. Military toxics do not seem to be very much unlike those found at civilian sites. However, some military-specific contaminants, such as chemical munitions and unexploded ordnance, do pose unique risks to human health and surrounding ecosystems. In Chapter 5, DOD's responsibility for dealing with these environmental dangers will be addressed.

Chapter 5

RESPONSIBILITY

Much like their industrial counterparts, the armed services have not considered the externalities and social costs of their endeavors, in this case, providing for our national defense. Our military toxic legacy is the result.

In this chapter, DOD's environmental management programs and its attempt at remedying past indiscretions will be addressed. Specific emphasis is given to Department of the Army programs, for which the Corps of Engineers is executive agent responsible for implementation. Additionally, the doctrines of "sovereign immunity" and "the unitary theory of the executive" are introduced.

THE MILITARY'S ENVIRONMENTAL PROGRAM

From the large amount of evidence available, it is clear that past environmental practices of the military have been negligent and reckless. Yet the military's current waste management practices continue to jeopardize the environment.[15] Recognizing this, the Congress enacted the Defense Environmental Restoration Act in 1986 which mandated that DOD establish the *Defense Environmental Restoration Program (DERP)*. This is the DOD-level response to contaminants generated by military commands and is the authority from which all other military environmental response programs spring. Each service has since established their own environmental restoration programs. The following discussion will concentrate on those effected by the Department of the Army (DA).

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[15] Siegel, et al, 24.

The *Installation Restoration Program (IRP)* is the DA plan for cleanup of its contaminated sites. It is a comprehensive effort by which DA will meet the standards and requirements of the DERP. Included in this are contracting mechanisms, public participation requirements, and directions for inter-agency coordination agreements with EPA, and state and local governments. The plan is published by the U. S. Army Toxic and Hazardous Materials Agency, an arm of the Corps of Engineers. Action responsibility for the success of the program is delegated to the installation engineer, known as the DEH (for Directorate of Engineering and Housing).[16]

The *Formerly Used Defense Sites (FUDS)* program (no relation to Elmer and his family) is DA's equivalent to Superfund. The purpose of this program is, as its name implies, to cleanup formerly used defense sites which are now either inactive or abandoned. Sites can be located on federal or private property with one or more

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[16] The specifics of this program are found in the **U. S. Army Installation Restoration Program Guidance and Procedure (December 1990)** prepared by the U. S. Army Corps of Engineers Toxic and Hazardous Materials Agency at Aberdeen Proving Grounds, MD.

responsible parties, that is, DOD and its contractors. The U. S. Army Corps of Engineers is the executive agency responsible for this program.

The *Integrated Hazardous Material / Hazardous Waste (HM/HW) Management Plan (DRAFT)*, now in its formative stages, is a draft program by which DA will reduce its hazardous waste generation by 50%, compared to its 1984 levels, prior to the end of fiscal year 1992. This waste minimization effort, as mandated by the Congress in the 1986 Defense Environmental Restoration Act and DOD in the DERP, is an attempt to bind DA agencies together through standardized reporting and monitoring procedures. As an action plan, it assigns responsibilities and timetables for completion of critical actions to specific DA agencies and major commands. The final plan is expected to be published in September of this year.

ASSESSMENT OF THE PROGRAM

The strength of the DERP is that it is an action program. It directs the armed services to produce measurable results in helping to mitigate the impacts of operations. This is not a significant departure from similar civilian programs. However, the organization within which action will be carried out is -- DOD is results oriented and task organized. The military's default setting is "action instead of deliberation" and "forgiveness rather than permission". This is probably the single most significant distinction between civilian sites and "military' toxic contamination.

However, DOD's program is beset with many weaknesses, some of which could compromise the entire defense environmental effort. First and foremost of these is inadequate coordination and centralized management of the services' environmental programs. Lacking the guidance and unifying force behind ... reporting requirement(s), there has been no unified reporting of military toxic releases. Instead, regulators and the public have been presented with Pentagon waste generation figures that are more like "guestimates" than hard numbers that such a serious issue demands.[17] The principle reason for this short-

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[17] Siegel, et al, 25-26.

fall is a lack of centralized control at DOD. Reporting procedures are different within and across the several armed services, with no standard binding their efforts together. The DERP does not provide specific enough guidance to solve this problem. **The result:** *DOD does not know the magnitude, toxicity, and destination of much of its hazardous wastes. This uncertainty impedes efficient cleanup efforts and programming of limited environmental dollars.*

Another significant shortfall is in the legal arena. The principles of "sovereign immunity" and the "unitary theory of the executive" preclude prosecution of DOD by stakeholders and executive agencies. The Justice Department contends that Federal Agencies are exempt from state (and local) enforcement under the doctrine of "sovereign immunity" and has refused to bring enforcement suits (on behalf of the EPA) against DOD, claiming that the "unitary theory of the executive" precludes one agency of the executive branch (EPA) from suing another (DOD).[18] The practical result of these views is that there is no downside risk for

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[18] Siegel, et al., 38.

the Defense Department in this very sensitive area. Without the specter of liability from litigation, a major force in the civilian environmental market, DOD can set its own agenda concerning site remediation, cleanup, and closure. In these times of budgetary constraints, fiscal crisis, and military cutbacks, limited resources are understandably directed at mission-essential tasks and away from the DERP. **The result:** *sites remain contaminated, contaminants continue to migrate off-site, and stakeholders have no legal mechanism through which they can influence the cause of the problem.*

The military's environmental record is less than sterling. Past practices and environmental ignorance have caused significant ecological harm and continue to pose risks to human health. Present DOD programs, though based in an action organization which speaks well for remediation, fall short of providing the information and opportunities necessary for credible management of this critical problem. In Chapter 6, the technical alternatives for remediation at contaminated sites will be presented. These technologies can be used at both military and civilian sites and further developed into better and more effective treatment trains for specific toxics and site conditions.

Chapter 6

TECHNICAL ALTERNATIVES

Our Nation's military toxic legacy, presented in Chapter 4, cannot be cleaned without technologies developed by private industry. This chapter presents a compendium of remediation technologies for use at contaminated sites. Developing treatment trains for use on specific contaminants at specific sites is also addressed. Finally, commercial application of these technologies is introduced.

Hazardous Waste Remediation, or "end-of-pipe" cleanup, is generally accomplished by using one or more of three (3) types of systems: 1) in situ, 2) prepared bed, and 3) in-tank reactor. **In situ** systems involve treating contaminated soils in-place, that is, where the contamination is located; contaminated soil is not moved from the ground. **Prepared bed** systems involve either 1) the physical removal of contaminated soil from its original site to a newly prepared area which has been designed to enhance treatment and/or prevent transport of contaminants from the site, or 2) movement of contaminated soil from the site to a storage area while the original location is prepared for use, after which the soil is returned to the bed, where treatment is accomplished. **In tank** systems involve removal of contaminated soil for treatment in an enclosed reactor based upon batch, complete mix, or plug flow systems.[19]

These three (3) systems employ one or more of several treatment technology classes: 1) biological, 2) chemical, 3) physical separation (component and phase), 4) stabilization, solidification, encapsulation, and 5) thermal.

[19] Ronald C. Sims, *Soil Remediation Techniques at Uncontrolled Hazardous Waste Sites: A Critical Review*, ***Journal of the Air Waste Management Association***, vol 40 no 5 (May 1990): 706.

Biological treatment involves employing bacteria, fungi, and/or microorganisms to alter or destroy the hazardous waste. Liquid and solid wastes that can be treated by this method may include toxic chlorinated and aromatic organic compounds. The process is highly sensitive to environmental conditions, including fluctuations in pH and temperature, and to changes in the concentrations of heavy metals and salts in the waste stream.

Chemical treatment of hazardous waste is accomplished through a chemical reaction in order to destroy the hazardous component. Wastes that can be treated by this method include both organic and inorganic compounds without heavy metals. Drawbacks to this method include the inhibition of the treatment process reaction by impurities in the waste and the potential generation of hazardous byproducts.

A **physical** treatment separates the hazardous waste from its carrier by various physical methods such as adsorption, distillation, and filtration. This class of treatment is applicable to a wide variety of wastes but further treatment is usually required.

Stabilization, Solidification, and Encapsulation processes isolate the hazardous waste from the surrounding environment without destroying the hazardous constituents. The treatment objective is normally achieved by mixing the waste with an inorganic compound such as fly ash, lime, clay, or Portland cement to form a chemically and mechanically stable solid. The treated waste generally has higher strength, lower permeability, and lower leachability than the untreated waste. This treatment class is applicable primarily to inorganic wastes containing heavy metals. Organic compounds often interfere with the setting action of the solidifying agent. There is no guarantee of the effectiveness of this method over time due to a lack of data on long term leachability studies. This type of treatment may be feasible for use at sites with limited space or in emergency actions to alter the form of the waste to a more easily transportable form.

Thermal treatment involves the decomposition of hazardous waste by thermal means into less hazardous or nonhazardous components. When subjected to high temperatures (2500-3000°F), organic wastes decompose to similar, less toxic forms. Complete combustion yields carbon dioxide and water plus small amounts of carbon monoxide, nitrous oxides, and chlorine and bromine acid gases. Some thermal processes produce off gases and ash that require further treatment or landfill disposal. This treatment class is most suitable for organic wastes and is less effective when attempting to detoxify heavy metals and inorganic compounds. Thermal treatment is often very expensive.

Alternative technologies for each of the five (5) treatment classes are presented in Tables 1 through 6. Applicable waste types, practical limitations, and special use considerations are also included. The development phases described for each technology are as follows: ***A*** *= Available Alternative Technology* indicates that a technology is fully proven and in routine commercial or private use; ***I*** *= Innovative Alternative Technology* describes a technology for which cost or performance information is incomplete, thus hindering routine use at hazardous waste sites (An innovative Alternative Technology requires full-scale field testing before it is considered proven and available for routine use); ***E*** = *Emerging Alternative Technology* signifies that the technology has not yet successfully passed laboratory or pilot-scale testing.[20]

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[20] Environmental Protection Agency, Office of Environmental Engineering and Technology Demonstration, **Guide to Treatment Technologies for Hazardous Wastes at Superfund Sites**, EPA/540/2-89/052 (Washington, D C: March 1989), 1.

TECHNOLOGY	APPLICABLE CONTAMINANTS	QUALIFYING FACTORS	PHASE[†]	MOBILE[‡]
Activated Sludge	Soluble organics in dilute aqueous streams (< 1% suspended solids).	· BOD < 11,000 ppm. · Requires low concentrations of heavy metals, PCBs, pesticides, oil, and grease.	A	X
Aerobic Treatment (sequential batch reactor, fluidized bed, fixed film fluidized bed with / without activated carbon, aerated biofilm reactor, membrane reactor).	Aqueous waste with low levels of nonhalogenated organics and certain halogenated organics (that is, phenols, formaldehyde, PCP).	· BOD < 10,000 ppm. · Requires consistent, stable operating conditions.	A	X
Anaerobic Treatment (fluidized bed, fixed film fluidized bed with / without activated carbon).	Aqueous slurry with low to moderate levels of nonchlorinated organic compounds containing < 7% solids.	· Requires consistent, stable operating conditions. · Unsuitable for oil and grease, aromatics, and long chain hydrocarbons.	A	X
Bacteria	PCBs and various other organic compounds in soils (that is, 2,4,5-T and 2,4-D).	· May involve genetic engineering. · Natural adaptation.	A	X
Composting	Aqueous sludge with < 50% solids, nonchlorinated hydrocarbons, high organic wastes including oils, tars, and industrial processing sludges.	· Requires nutrient supplementations. · Output sludge contains heavy metals.	A	X
Enzyme Treatment	Soluble organics in dilute aqueous waste streams.	· Requires stable influent concentration.	E	X
Lagoons and Ponds	Industrial wastewater, organics with slow biodegradation potential, soluble organics in dilute aqueous waste streams.	· Requires large area. · Unsuitable for solids. · Requires temperate climate. · Output sludge contains heavy metals and refractory organics which require further treatment.	A	
Mycorrhizas	Soil-entrained hazardous waste constituents.		E	X
Rotating Biological Contactor	Biodegradable dilute aqueous organic waste including solvents and halogenated organics.	· Limited to low concentrations of heavy metals and concentrated refractory organics. · Unsuitable for sludges or solids.	A	X
Trickling Filter	Soluble organics in dilute aqueous streams with < 1% suspended solids including solvents and halogenated organics.	· BOD < 5,000 ppm. · Output sludge contains heavy metals and refractory organics which require further treatment.	A	X
White Rot Fungus *(Phanerochaete chrysosporium)*	Toxic or refractory halogenated organics in soil (that is, 2,3,7,8-TCDD, DDT, mirex, lindane, hexachlorobenzene).		E	X
Yeast Strains	Halogenated organics.	· Involves genetic engineering.	E	X

[†] **PHASE** - Phase of Development; A = Available, I = Innovative, E = Emerging
[‡] **MOBILE** - Transportable

Table 4-1. Biological Treatment Technologies.[21]

[21] Environmental Protection Agency, EPA/540/2-89/052, March 1989, 5.

TECHNOLOGY	APPLICABLE CONTAMINANTS	QUALIFYING FACTORS	PHASE[1]	MOBILE[2]
Chlorinolysis	Concentrated liquid chlorinated organic waste streams with low concentrations of sulfur and oxygen.	· Unsuitable for solids and tars. · Unsuitable for benzene and aromatics. · Output carbon tetrachloride can be recovered.	I	
Dehalogenation (including use of the Alkali Metal Polyethylene Glycol Reagent - APEG).	Halogenated organics in soils and sludges that are partially dehydrated (that is, PCBs, dioxins).	· Requires heat and excess reagent.	I	X
Electrochemical Dehalogenation	Halogenated organics (that is, PCBs).	· Not known.	E	
Electrolytic Oxidation	High concentration cyanide (10%) and metals wastes.	· Suitable for low solid content wastes.	A	
Hydrolysis	Solids, soils, sludges, slurries, or liquids contaminated with organic compounds.	· Requires careful handling of strong acids and alkalines. · Reaction is performed at high temperatures and pressure requiring close monitoring.	A	X
Ion Exchange	Aqueous organic or inorganic waste streams, principally metals.	· Suitable for liquid waste only.	A	X
Lignin Adsorption	Aqueous organic or inorganic waste streams.	· Not known.	E	X
Neutralization	Corrosive liquid wastes, both acids and bases.	· Unsuitable for sludges and solids. · Requires corrosion resistant equipment.	A	X
Oxidation (chlorination, ozonation, hydrogen peroxide, potassium permanganate, chlorine dioxide, hypochlorites).	Dilute aqueous waste (< 1% waste) containing organic / inorganic compounds.	· Requires controlled reaction conditions. · Suitable for liquids and sludges only.	A	X
Polymerization	Organic compounds such as aromatics, aliphatics, and oxygenated monomers.	· Application is limited to spills.	I	X
Precipitation	Aqueous organic and inorganic waste containing metals.	· Requires optimization of the reaction pH for the specific mix of metals present. · Output sludge requires further treatment. · Cross-reactivity may occur for mixed-metals content waste. · Unsuitable for sludges, tars, and slurries.	A	X
Reduction (Sulfur dioxide, sodium borohydride sulfite salts, ruthenium tetraoxide).	Dilute aqueous waste stream containing inorganic compounds, especially metals (< 1% heavy metal concentration).	· Applicable to inorganic waste only. · Suitable for liquid waste only.	I	X
UV / Photolysis	Liquid waste containing dioxins.	· Suitable for liquid wastes only.	E	X

[1] **PHASE** - Phase of Development; A = Available, I = Innovative, E = Emerging
[2] **MOBILE** - Transportable

Table 4-2. Chemical Treatment Technologies.[22]

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[22] Environmental Protection Agency, EPA/540/2-89/052, March 1989, 8.

TECHNOLOGY	APPLICABLE CONTAMINANTS	QUALIFYING FACTORS	PHASE[†]	MOBILE[‡]
Air Flotation (dissolved or induced)	Liquid waste containing oils or light suspended solids.	· Liquid effluent may require further treatment.	A	X
Centrifugation (bowl, basket, disk).	Organic / inorganic liquids, slurries, and sludges containing suspended or dissolved solids or liquids where one component is nonvolatile. For example, wastewater sludge, wastes containing immiscible liquids, or wastes containing three (3) distinct phases.	· Unsuitable for tars, solids, dry powders, or gases. · Not applicable for small size or low density particles.	A	X
FILTRATION:				
Belt Filter Press	Biological and industrial sludges.	· Filter cake may require further treatment.	A	X
Chamber Pressure Filtration (pressure leaf, tube element, plate and frame, horizontal plate)	Wastewater sludges, or sludges with a flocculated or adhesive nature.	· Dewatering technology. · Unsuitable for sticky or gelatinous sludges.	A	X
Granular Media Filtration	Liquid waste containing suspended solids and / or oils.	· Requires frequent backwashing. · Requires pretreatment for suspended solids with concentration < 100 mg/l.	A	X
Vacuum Filtration (fixed media, rotary drum)	Organic or inorganic chemical sludges, metals, and cyanides bound up in hydroxide sludges.	· Dewatering technology. · Unsuitable for sticky or gelatinous sludges.	A	X
Gravity Separation (coagulation, flocculation, sedimentation)	Liquid waste containing settleable suspended solids, oils, and / or grease.	· Liquid effluent may require further treatment. · Unsuitable for heavy slurries, sludges, or tars.	A	X
***In Situ* Soil Extraction**	Soils with low levels of organics or inorganics / metals contamination.	· Unsuitable for dry or organic-rich soils.	E	X

[†] PHASE - Phase of Development; A = Available, I = Innovative, E = Emerging
[‡] MOBILE - Transportable

Table 4-3. Physical Treatment Technologies (*Component Separation*).[23]

[23] Environmental Protection Agency, EPA/540/2-89/052, March 1989, 11.

TECHNOLOGY	APPLICABLE CONTAMINANTS	QUALIFYING FACTORS	PHASE[†]	MOBILE[‡]
Air Stripping	Aqueous and adsorbed organic and inorganic wastes with relatively high volatility and low water solubility such as chlorinated organics, aromatics, and ammonia.	· Limited to VOC concentration < 100 ppm. · Suspended solids may clog tower.	A	X
Carbon Adsorption	Aqueous organic wastes (containing < 1% total organics and < 50 ppm solids) with high molecular weight and boiling point, and low water solubility, polarity, and ionization.	· Unsuitable for metals. · Unsuitable for oil and grease.	A	X
Colloidal Gas Aphrons (CGAs) (enhances air stripping and biodegradation).	Soils contaminated with phenols, phthalate esters, aromatic hydrocarbons, aliphatic hydrocarbons, chlorinated hydrocarbons, amines, and alcohols.	· Hydraulic conductivity of the soil must be > 10^{-4} cm/sec.	E	X
Distillation	Liquid organic mixtures with low viscosity that can be separated due to molecular weight / volatility differences.	· Unsuitable for thick polymeric materials, slurries, sludges, or tars.	A	X
Electrokinetics	Soils contaminated with organic or inorganic waste.	· Soil matrix must be relatively permeable and saturated.	I	
Evaporation	Organic / inorganic liquid solvents contaminated with nonvolatile impurities (that is, oils, grease, paint solvents, polymeric resins).	· Liquids must be volatile. · Unsuitable for tars, solids, dry powders, or gases. · Energy-intensive process.	E	X
Freeze Crystallization	Dilute aqueous organic / inorganic waste solutions containing < 10% total dissolved solids.	· Unsuitable for foamy, viscous, or high solid content waste streams.	E	X
Mechanical Soil Aeration	Volatile organics in sludge and soil.	· Effluent may require further treatment.	A	X
Metal Binding	Metal-contaminated aqueous streams, leachate, or groundwater.	· Limited to metal concentrations between 500-1000 ppm.	E	
Resin Adsorption	Aqueous waste streams containing soluble organics, particularly phenols and explosive materials.	· Limited to low concentrations of organics (< 8%) and suspended solids (< 50 ppm).	A	
Reverse Osmosis	Aqueous waste streams containing < 400 ppm heavy metals, high molecular weight organics, and dissolved gases.	· Unsuitable for oxidants. · Requires controlled pH, low concentration of suspended solids.	I	X
Solvent Extraction	Aqueous stream contaminated with single- or multi-component dissolved organic wastes. Sludge contaminated with oils, toxic organics, and heavy metals.	· Extracting solvent must be immiscible in the liquid and differ in density so gravity separation is possible. · Suitable for sludges containing < 20 wt % oil / organics and < 20 wt % solids.	A, I	X
Steam Stripping	Aqueous solutions of volatile organics.	· Effluent may require further treatment. · Suitable for waste streams with low metal concentration.	A	X
Supercritical Extraction	Sludge, solids, or liquids contaminated with organics.	· Effluent may require further treatment.	E	X
Ultrafiltration	Removes oils, metals, and proteins from aqueous solutions with dissolved organics, emulsions, and colloidal particles.	· Limited to low concentrations of suspended solids.		

[†] PHASE - Phase of Development; A = Available, I = Innovative, E = Emerging
[‡] MOBILE - Transportable

Table 4-4. Physical Treatment Technologies (*Phase Separation*).[24]

[24] Environmental Protection Agency, EPA/540/2-89/052, March 1989, 13.

TECHNOLOGY	APPLICABLE CONTAMINANTS	QUALIFYING FACTORS	PHASE[†]	MOBILE[‡]
Cement-based Fixation	Treated sludges and soils containing metal cations, radioactive wastes, and solid organics (that is plastics, resins, tars).	· Long term stability / leachability is unknown. · Lignite, silt, and clay increase setting time. · Dissolved sulfate salts, borates, ans arsenates must be limited.	A	X
Macro-Encapsulation, Overpacking, Thermoplastic and Thermosetting Techniques	Chemically or mechanically stabilized organic, inorganic, and radioactive wastes.	· Encapsulating matrix must be compatible with waste. · Long term leachability unknown, therefore, waste storage must be considered. · Requires specialized equipment.	A	X
Pozzolanic-based Fixation (fly ash, lime based)	Treated sludges and soils containing heavy metals, waste oils, solvents, and low level radioactive waste.	· Borates, sulfates, and carbohydrates interfere with the process · Long term stability / leachability is unknown.	A	X
Sorptive Clays (treated, chemically modified)	Halogenated organic compounds and heavy metals.	· Long term leaching is a problem, therefore, waste storage must be considered.	I	X
Vitrification	Soils contaminated with organic, inorganic, and radioactive wastes.	· Limited to soils with high silica content.	A, I	X

[†] **PHASE** - Phase of Development; A = Available, I = Innovative, E = Emerging
[‡] **MOBILE** - Transportable

Table 4-5. Stabilization / Solidification / Encapsulation Treatment Technologies.[25]

[25] Environmental Protection Agency, EPA/540/2-89/052, March 1989, 16.

TECHNOLOGY	APPLICABLE CONTAMINANTS	QUALIFYING FACTORS	PHASE†	MOBILE‡
Electric Reactor	Soil contaminated with solid and liquid organics and inorganics.	· Contaminated soil must be finely divided and dry.	I	X
Fixed Hearth	Bulky solids, liquids, and sludges.	· Particle size must be large enough not to fall through grate.	A	
Fluidized Bed	Organic solids, liquids, and sludges.	· Requires low water and inert solid content.	A	X
Industrial Boiler	Granulated solids, liquids, and sludges.	· Requires low chlorine and sulfur content. · Ash content clogs system. · Small particle size.	A	
Industrial Kiln	Spent pot lining, nonhalogenated oils, and PCB-contaminated liquids and sludges.	· Requires low chlorine and sulfur content.	A	
Infrared Incineration	Soils, solids, and sludges contaminated with organic compounds (that is, PCBs, dioxins, explosives).	· Primarily for solid organic waste. · Heavy metals are not fixed in ash.	A	X
Liquid Injection	Pumpable liquid organic waste.	· Unsuitable for inorganic content and heavy metal content wastes. · Chlorinated solvents cause accelerated corrosion rates.	A	X
Molten Glass	Organic solids, liquids, gases, sludges (that is, plastics, PCBs, asphalt, pesticides).	· Sodium sulfates must be limited to < 1% content. · Inappropriate for soils and high ash content waste.	I	
Molten Salt	Low ash content waste, low water content liquid, or solid waste.	· Corrosion problems. · Requires frequent bed replacement.	I	X
Multiple Hearth	Granulated solids, sludges, tars, liquids, and gaseous combustible waste.	· Water, salt, and metal content must be limited. · Particle size must be small enough to pass through injector nozzles. · Not recommended for hazardous wastes.	A	
Plasma Systems	Liquid organic wastes (that is, pesticides, dioxins, PCBs, halogenated organics).	· Liquids only.		X
Pure Oxygen Burner	Liquid wastes which require high temperatures for destruction or have low heating values.	· Requires specially engineered nozzles to atomize the liquid waste.		X
Pyrolysis	Viscous liquids, sludges, solids, high ash content materials, salts and metals, and halogenated waste.	· Requires homogeneous waste input. · Metals and salts in the residue can be leachable.		X
Radio Frequency Thermal Heating	Volatile, low boiling point, or easily decomposed organic compounds in soil.	· Not known.	I	X
Rotary Kiln	Solid, liquid, or gaseous organic waste.	· Containerized wastes are difficult to handle. · High inorganic salt or heavy metal content wastes require special consideration. · Fine particulate matter must be limited.	A	X
Supercritical Water Oxidation	Aqueous organic solution / slurry or mixed organic / inorganic waste.	· Not known.	I	X
Wet Air Oxidation	Aqueous waste streams (< %5) with dissolved or suspended volatile organic substances.	· Unsuitable for solids, viscous liquids, or highly halogenated organic compounds. · Not economical for dilute or concentrated waste.	A	X

† **PHASE** - Phase of Development; A = Available, I = Innovative, E = Emerging
‡ **MOBILE** - Transportable

Table 4-6. Thermal Treatment Technologies.[26]

[26] Environmental Protection Agency, EPA/540/2-89/052, March 1989, 17.

Treatment technologies and systems may be combined to form chemical- and site-specific *treatment trains*, which can be selected to address specific waste escape pathways and phases during remediation. Evaluation for each possible combination of technologies and systems is based on a chemical mass balance approach through time to identify the fate of each waste. However, the lack of approaches for this sort of evaluation remains a current, major deficiency in the area of subsurface remediation, including soil remediation. In fact, two major problems with regard to meeting soil remediation requirements have been 1) lack of availability of appropriate technologies, and 2) lack of methods and approaches for evaluating and selecting remedial technologies for specific site-waste scenarios, especially with regard to *in situ* remediation.[27]

Commercial application of alternative technologies and treatment trains relies heavily on solving these selection and evaluation deficiencies. Scientific endeavor alone is clearly inadequate; developing new technologies is only the beginning. Remediation of

[27] Sims 1990, 706.

contaminated soils is a national priority of the highest order which must be addressed with urgency, and most of all, with action. The nature of the hazardous waste management industry must first be examined to understand the strategic forces at work. Then, a policy may be adopted for employing our national resources, such as the U S Army Corps of Engineers, towards prompt cleanup and privatization of that process.

In the next chapter, just such an analysis of the hazardous waste management industry is performed. The tools used in the analysis are the models presented by Porter in **Competitive Strategy** and **Competitive Advantage**.

Chapter 7

STRATEGIC MARKET ANALYSIS

As presented in Chapter 6, commercial application of the remediation technologies and treatment trains available cannot be successfully effected without first understanding the structure of the Hazardous Waste Management industry and the competitive forces at work. This chapter uses Porter's market segmentation, five (5) competitive forces, and value-added chain models to perform the analysis. The role of the U. S Army Corps of Engineers in this vital and growing industry is also discussed.

MARKET SEGMENTATION

The Hazardous Waste Management industry consists of four (4) segments: 1) Laboratory Analysis, 2) Engineering, 3) Remediation, and 4) Treatment, Storage, and Disposal. In the spectrum of Corps missions, Hazardous Waste Management falls under Facilities Engineering / Management, where an engineer and his staff maintain Army installations, from energy production to trash disposal. The four (4) segments are handled, in varying degrees, both at the installation level and in engineering divisions and labs around the world. As the world's largest purchaser of construction services, the Corps plays an important role in domestic construction. Consequently, the construction - oriented remediation segment becomes particularly important.

The customers serviced by the Corps and its fleet of contractors are 1) federal agencies, such as the Department of Defense, the Department of the Army, and the Environmental Protection Agency, 2) state governments, in cost-sharing scenarios, and 3) others, usually governments of U. S. Territories such as American Samoa. The most important of these three (3) are the federal agencies, specifically the Department of Defense, where base closures and cleanup of aging installations are now top priorities and promise to be Herculean tasks.

The products and services provided by the Corps include 1) construction management, 2) engineering and design, 3) laboratory support, 4) real estate development and management, 4) emergency operations, and 5) regulatory functions. Additionally, the Corps has various mobilization and wartime missions that support not only U. S. military operations, but also secure and maintain the nation's infrastructure.

Construction Management, under either military or civil works funding, is provided within the dictates of the Federal Acquisition Regulation (FAR) and its Army and Corps supplements. The primary mechanism for bringing completed construction to the customer is the fixed price contract secured through competitive, sealed bidding. All Corps construction is performed under contract - the Corps has no organic civilian construction assets. Engineering and design is performed either by in-house engineers or through negotiated, open-end design contracts with regional and local architect-engineer (AE) firms. Laboratory services are accomplished at all of the Corps divisions and at the three (3) Corps labs, as well as by private agencies employed by contractors during construction. Real estate development and management are functions which have been developed through vertical integration along the Corps Value Chain and deal with Army or Defense Department lands. Emergency operations are also provided at the Corps divisions to assist the Federal Emergency Management Agency (FEMA) with damage assessments and emergency construction management during national emergencies and disasters (hurricanes and earthquakes). Corps regulatory functions pertain to the nation's waterways and are also performed at all Corps divisions.

With regard to Hazardous Waste Remediation, the Corps is providing construction management services for the Defense Department ($1 billion budget for 1991 under the Defense Environmental Restoration Program)[28]

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[28] ————————, *DOD Reveals Cleanup Details*, **Engineer News Record**, 26 November 1990, 10. The Defense Environmental Restoration Program (DERP) was discussed in Chapter 5 of this thesis.

and the Environmental Protection Agency under the Comprehensive Environmental Response, Compensation and Liability Act (Superfund).

Waste Remediation market trends are very promising for the short and medium term. Since 1980, government and industry have spent between $5 and $10 billion on Superfund cleanup projects alone. This represents only a fraction of the ultimate amount, which will increase directly with the number of federal regulations, toxins, and public anxieties. The General Accounting Office estimates that over 425,000 sites may eventually require cleanup;[29] there are presently 1,236 sites identified on the Superfund National Priorities List, only 54 of which have been permanently dealt with.[30]

In the long term, hazardous waste remediation will give way to more encompassing measures of waste management, where producers will try to reduce their volumes of toxic output through recycling and better

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[29] Debra K. Rubin, *Cleanup Dollars Flow Like Water But Industry Awash In Problems*, **Engineer News Record**, 9 March 1989, 30.

[30] ————, *Superfund Is Making Strides, But It Still Has A Dark Side*, **Engineer News Record**, 26 November 1990, 128.

housekeeping.[31] However, even with significant environmental improvements in production processes and scale economies in on-site waste treatment, the nature and track record of Superfund suggest a bright future for remediation services.

FIVE (5) COMPETITIVE FORCES

Threat of New Entrants

The potential for significant financial gain makes this industry segment especially attractive. Consequently, the attractiveness to new entrants is HIGH and will remain so for the foreseeable future. With the enormous number of potential sites and increasing estimates of cleanup costs, this threat will continue to rise with time.

Barriers to entry are significant in this market segment and mitigate the threat described above, but by no means eliminate it. Regulatory uncertainties, man-

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[31] David J. Hanson, *Hazardous Waste Management: Planning To Avoid Future Problems*, **C&EN**, 31 July 1989, 14.

agement inexperience, and lack of trained personnel (most important for smaller firms) make entry into waste remediation a difficult task.[32] Additional barriers include significant capital investments for remediation and testing equipment, risks of future litigation (probably the most noteworthy of all), inadequate or unavailable bonding, and the slow pace of the Superfund program. Economic uncertainty (recession) also looms as a real barrier for new entrants, especially smaller firms. Along with capital investment, it poses a formidable barrier to exit which firms must consider before making the corporate leap into this segment.

The remediation market is very consolidated for the construction industry, with 70% of revenues now collected by 10% of companies. The percentage of revenues for these few large firms is expected to rise in the next ten (10) years as the industry continues to consolidate and rationalize the inherent risks and potential benefits.[33] Consequently, potential entrants will

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[32] Rubin, 30.

[33] Hanson, 17.

be larger firms who are able to muster the financial and technical muscle to capture new contracts. A recent Corps initiative in decentralizing procurement of remediation services has yet to change this proposition. The hope is that with decentralized control over remediation contracts, the Corps can involve more small contractors and increase the number of participating firms.[34] Another possible threat might be posed by foreign firms competing on a technological "fast follower" strategy, much like Japanese firms who acquire or copy already proven methods and apply them in more efficient ways to the production process. When one also considers the significant cost of capital advantage enjoyed by Japanese firms over their American counterparts, this set of potential entrants will represent a real threat, once new technologies are developed. Finally, major construction firms not presently competing in this segment are showing greater interest and their presence is being increasingly felt. Also marshalling their forces to penetrate the market are the waste generators (big industry) themselves.[35]

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[34] *DOD Reveals Cleanup Details*, 10.

[35] Rubin, 36.

Threat of Substitute Products or Services

The threat of substitutes is LOW, primarily due to specific guidance and tolerances in the federal regulations. The threat, if there is one, is in new and different remediation technologies. However, considering the barriers to entry discussed above, the generally uncertain nature of remediation, and our federal free market economic policies, such a threat is not formidable at this time. Though many firms are researching new remediation technologies, their implementation will be guarded, at best; they will present no challenge to proven practices until economic policies change to nurture domestic technological growth.

Buyer / Supplier Power

Buyer power and supplier power are both HIGH. Buyers of Corps (and their contractors) services brandish the threat of litigation, demanding 100% quality assurances. Suppliers of remediation services run the "only show in town" at the present time and can extract significant premiums, if not monopoly rents. The Corps may be immune to some of this power, but its remediation contractors view the influence as additional uncertainty to be programmed into their risk premiums.

Rivalry Among Existing Firms

Rivalry among the few large firms in this segment is HIGH, considering the expected future boom in remediation work. However, with time, this rivalry will become more widespread to include smaller, niche competitors championing new remediation technologies. Additionally, as industry experience becomes more widespread, both in the technical and business areas, rivalry will jump accordingly.

VALUE - ADDED CHAIN

Linkages

From its long history as the government's construction agent, the Corps enjoys significant linkages within its own Value Chain, with the construction industry, and with other industries. Solution mechanisms for the waste remediation missions assigned by our federal civilian leadership are well established.

Within the framework of the Corps' remediation mission, technology links construction operations with all other Value Chain activities and is central to the global development of this industry segment. New remediation technologies are the key to improved competition and efficiency which, in turn, impact Corps mission accomplishment. A combination of new remediation technologies and alternate procurement methods would reduce the risks now experienced by contractors, encourage innovation during construction, and generally feed new information back into the construction system. The synergy of information sharing in this way would increase contractor proficiency and result in a better service for Corps customers. Additionally, the Corps would act as a "testing bed" for new processes and as a "farm system" of human resource development for the industry.

Market Imperfections

Imperfections in the present system deal primarily with the inefficient allocation of risk between the Corps and its contractors. This springs from the traditional procurement methods currently in use and their inherent adversarial, self-serving, and litigious nature.

If technological innovation drives true progress in this market segment, then traditional procurement methods are obviously inappropriate. To encourage technological innovation, a more cooperative approach to contracting must be employed. Alternative contracting methods will better allocate risks between the contract parties and facilitate more innovative approaches to remediation projects. Biddability, constructability, and value engineering are inherent in the process, resulting in better designs, reduced delivery times, reduced costs, and improved service.

The obstacles to entry into this very important and dynamic market should not be bureaucratic or procurement based. In a risky business such as waste remediation, which is so potentially vital to the nation and our technology base, innovative management must guide the technological innovations it seeks. Alternative contracting measures cannot dispel the risks of litigation, reduce the costs of American capital, or reconcile the short-term expectations of financiers with the long-term aspirations of industry. However, they can create an environment where innovation is strategically, operationally, and economically feasible.

In the next chapter, a prescription for the U.S Army Corps of Engineers as facilitator of technological development in this industry is presented.

Chapter 8

The U.S. ARMY CORPS of ENGINEERS

The U. S. Army Corps of Engineers has a distinct responsibility and unique aptitude to assume a leadership role in resolving our environmental dilemmas. Besides the pure existential engineering joys of meeting tough challenges with informed solutions, the Corps, as the Nation's Engineer, has both the moral and professional responsibility for providing, at the least, technically and scientifically feasible alternatives. This is not just wishful thinking, however. The Corps has had over a century of experience in solving tough problems and, in that time, has developed relationships with society and the business community which speak highly for its role as an intermediary and coordinator in what will surely be dispute resolution rather than an application of technology. In addition, the Corps is a stable, government organization, capable of bearing significantly more financial and operating risks than even the largest of America's corporations. If for no other reason than this, the Corps is an ideal vehicle for insurance underwriting and for information gathering at significantly reduced costs. Both the opportunity costs of inaction and those of misguided actions can be mitigated in this reduced risk arena.

Achieving goals means applying science to situations the best way we know - in other words, taking risks.[36] The Corps' capacity to assume considerable risks in developing solutions for unique problems is particularly noteworthy when considering the environment. Remediation of hazardous chemical wastes and disposal of nuclear spent fuels are inherently uncertain propositions. Private investment in any one of these endeavors would be at significantly higher costs and require equally substantial returns on

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[36] William L. Robertson, *To Be Environmental Engineers For The Nation*, **Strategic Working Paper #89-3**, 11 April 1989, 4.

investment. Our increasingly litigious society, as previously discussed, makes such ventures nearly impossible, especially for smaller firms attempting to penetrate the market with innovative products or processes. Without some sort of subsidy, the market will tend to force new players from the scene and encourage overall inefficiency. It is here that the Corps should assume a leadership role in technological innovation and privatization of the process. Through alternative procurement mechanisms, such as design-build or other turnkey approaches, the Corps can mitigate the risks of the market. It can also pursue traditional competitively bid contracts for innovative projects, but hold contractors liable only to the limits of the contract, not to the standards of processes yet to be developed. In this way, contractors are de facto indemnified if a new energy or remediation technology is a loser; the Corps assumes the ex post facto risks of technological failure. Therefore, the technology is at risk, not the contractor. Such a method delivers the needed subsidy in the form of risk mitigation resulting in correspondingly lower costs of capital, bid bonding, and performance insurance. Overall contract costs are lower with, in the case of alternative procurement mechanisms, constructability engineered directly into the design making the final product more sound, both technically and financially. Innovative technologies for hazardous waste remediation brought to the market at a lower cost and quicker, provide more and better information to our national policy-makers and scientists for even more informed and legitimate decisions. The opportunity costs of inaction and misguided actions are mitigated, preserving the decision environment for our progeny. Our technology base is strengthened, thereby increasing our Nation's competitiveness abroad, allowing us a better hold on our commitment to the future.

The Corps also has a responsibility as the Nation's Engineers for developing new and better technologies to allay the consequences of our industrial activities. Our new found public awareness concerning the environment has not yet been translated into remedial action on a large enough scale to effect real change. Now, more than ever, engineering skills and tools are needed to achieve environmental ends.[37] However, engineering

[37] Robertson, 3.

is not simply the technical proposal of new and innovative methods and mechanisms. Part and parcel to engineering solutions is economic feasibility. A properly prepared engineering solution is the optimal combination of technical alternatives and available economic resources. Ultimately, engineers must present their solutions in a format acceptable to audiences of diverse political convictions and scientific aptitudes. This is the forte, and mission, of the Corps.

Engineering skills and tools are abundant within the Corps, both at its operating engineering divisions and in its three (3) central laboratories. Also organic to the organization are the construction elements of each division which actually administer contracts around the world. The synergy of using both to effectively develop new and better technologies for our common environmentally - safe future is obvious. Balancing tasks and budgets is a daily function within the Corps, one which it takes seriously, along with presenting engineering solutions at public forums, a common part of all civil works projects. Above and beyond these wealth of attributes is the fact that the Corps is an agent of our government and our national policy. It has its finger on the pulse of national sentiment and our policy-makers' desires, along with understanding its greater task of maintaining the Nation's trust. The Corps is central to coordinating the engineering solutions to our environmental problems and presenting them to our Nation. Hopefully, our national civilian leadership recognizes this and will utilize the Corps' strengths to a greater degree in the future - for the future.

In the next chapter, some conclusions and recommendations from my research are presented, with specific emphasis on our military toxic legacy and employing the Corps as a *test bed* or *incubator* for innovative remediation technologies and construction programs.

Chapter 9

CONCLUSIONS and RECOMMENDATIONS

Commentary on our nation's toxic legacy cannot, unfortunately, be comprehensively made here. In this chapter, some of the major conclusions and recommendations resulting from my research are presented. The list is by no means exhaustive. Additionally, I offer some prescriptions for the Department of Defense in improving their environmental programs and remediation efforts. Again, the list is just the "tip of the ice-berg."

MILITARY IS NATION'S WORST POLLUTER

As the discovery process continues, more and more contaminated "hot spots" will be uncovered. The problems surrounding currently identified sites will continue to confound decision-makers if immediate and effective response actions are not effected. Cleanup of contaminants from the past is only part of the solution, however. Process and program overhaul to effectively monitor and manifest the disposal of currently generated wastes must be implemented. Waste minimization strategies, such as those outlined in the Five-year Integrated Hazardous Material / Hazardous Waste Management Plan (DRAFT) must also be brought to fruition; end-of-pipe treatments are well-known to be more expensive and environmental unsound than process modifications to reduce waste generation at its sources. Substitution of less toxic substances in processes is a step in the right direction.

Scaling down military programs and operations in recognition of the decreased strategic Soviet threat around the world is already in the works. From the environmental standpoint, this could be a boon to the effort of reducing military environmental destruction. However, it is a precarious assertion that this alone will allay further damage or even greatly diminish it. DOD must design into its daily activities a consideration for environmental matters. Not only must the industrial processes of weapons and chemicals manufacture be realigned along environmentally sound lines, so must maintaining the readiness of the force. Soldiers and sailors must be educated, as should their civilian counterparts, to respect environmental concerns at all times. They will use this knowledge as members of the armed forces to help change its course to a more environmentally enlightened path. They will also carry this knowledge back with them when transitioning from military to civilian careers as their service obligations terminate. Losing this mechanism for environmental action, both inside and outside of the military, would be criminal.

MILITARY'S PROGRAM HAS PROBLEMS

The Defense Department's hazardous waste cleanup programs are beset with problems which, unresolved, will further hinder efforts towards timely and effective solutions. Standardized reporting procedures and ingraining a bone-deep environmental ethic are critical to success. In addition, the legal issues of "sovereign immunity" and "unitary theory of the executive" must be addressed. Litigation is not the key, however, as it is, historically, a stumbling block to swift environmental remedy. Interagency agreements, as outlined in the IRP, may be the tool through which stakeholder concerns can be equitably addressed. The critical issue, as with Superfund sites, is a balance between litigation, regulation, and remedy. The Superfund program has failed in this regard, placing too much faith in tort law as the enforcement / compliance vehicle. DOD is in a unique position to establish such a balance and, perhaps, develop a model after which other NPL sites across the country could pattern their efforts.

"TEST BED" OR "INCUBATOR" FOR NEW REMEDIATION PROGRAMS

The magnitude of our military's toxic inventory and the number of DOD sites presently listed for further remedial action speak well for using this arena as a test bed or incubator in developing new and innovative remediation technologies and administrative procedures. Lessons learned from other environmental programs (Superfund, for example) should be drawn upon in this regard. Emphasis should be on action rather than study to mitigate the environmental opportunity costs of a delayed response, whether caused by the lack of appropriate technologies or bureaucratic inertia in the name of scientific deliberation. Newly developed action programs and remediation technologies could be directly transplanted to similar civilian sites to help streamline cleanup. Alternatively, the U. S. Army Corps of Engineers, as the agent of innovation in the DOD toxic arena, could be given universal oversight, responsibility, and resources for the nation's remediation responsibilities.

MILITARY'S PROGRAM MUST BE CREDIBLE

The Defense Department cannot hide behind the Veil of National Security in pursuing this program. If it is to succeed, it must be considered credible by the stakeholders involved -- lawmakers, environmental groups, the scientific community, and local concerned citizens. This should involve a more participatory approach, specifically, the Co-production model described by Susskind and Elliot.[38] Presently, the action for public involvement is delegated to local commands' Public Affairs Offices. As a risk mitigation tool, as well as a joint fact-finding and education vehicle, commanders must further interact with stake-holders to ensure their support and confidence, up front. However, public participation and stakeholder involvement should not hinder DOD's environmental response. Credibility is earned from results and deeds, not rhetoric and hand-waving. DOD has the opportunity to materially effect the environmental

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[38] Lawrence Susskind and Michael Elliot, *Learning from Citizen Participation and Citizen Action in Western Europe*, **The Journal of Applied Behavioral Science** vol 17 no 4 (1981): 500.

health of the nation, in a positive way, and should realize that all parties' concerns will necessarily not be satisfied, as they conflict in many regards. Action, not deliberation, is the key.

The military's toxic legacy is one of immense proportions. As bases are closed and the size of the force is scaled back in response to the decreasing strategic threat from abroad, "peace dividends" will be targeted at environmental restoration. Because of its action orientation and insolation from the liability of litigation, DOD has a unique opportunity to materially affect the environmental health of our nation in a positive way. Part and parcel to this is developing new and innovative action programs and remediation technologies which could be transplanted directly to private sites. As the nation's engineers and action agent for DA's programs, the U. S. Army Corps of Engineers can help generate the success stories necessary to sell the Congress on assigning them the nation's overall remediation mission. With the "big blip on the screen" (1995 Superfund Reauthorization) not too far away, this should be a primary focus for the Corps in the near-term. In the long-term, the consideration should shift to commercialization and practical application of new remediation technologies and action programs to help bolster our domestic contractor and technology bases, further enhancing our competitiveness in global circles.

In the final chapter of this thesis, I offer some suggestions for further research that would be important to a better understanding of hazardous waste remediation projects and the U. S. Army Corps of Engineers' role in managing them.

Chapter 10

FURTHER RESEARCH REQUIRED

In this chapter, I offer some suggestions for further research in this area. Specifically, two (2) topics are presented, both from the field of construction finance: 1) evaluating alternative contracting mechanisms for hazardous waste remediation projects and 2) sophisticated project valuation models for use with all U. S. Army Cops of Engineers projects.

As discussed, the U. S. Army Corps of Engineers, in accordance with Superfund, SARA, the Defense Environmental Restoration Program (DERP), and the Installation Restoration Program (IRP), has become responsible for remediation and closure of the hundreds of severely contaminated active military installations and abandoned sites, along with bases earmarked for closure. As the Defense Department scales its operation down according to new missions and a reduced strategic Soviet military threat, the "peace dividend" resulting therefrom is being guided to environmental restoration targets. As the nation's engineers and the government's construction agent, the Corps is now tasked with effectively allocating these new resources to Army sites needing remediation.

Several issues arise which are of import to remediation efforts and, specifically, the construction field. First, as the government's construction agent, the Corps has at its disposal several forms of contracting mechanisms, not all of which equitably allocate operational or financial risks among the parties. Investigating how different contracting mechanisms can be utilized to perform cleanups while also reallocating risks more equitably would be of considerable value. Second, the valuation of these projects is normally not accomplished with more sophisticated procedures, such as Valuation by Components (VC) or

Option Models (Black-Scholes). Investigating the value of remediation projects with these methods would be an important step toward a better understanding of their long term, life cycle nature. Finally, justifying how the Corps could justify taking responsibility for the Superfund cleanup program from EPA would be of significant interest -- not only for a Corps Officer looking for future projects, but also from a construction management and environmental optimization view.

ALTERNATIVE CONTRACTING MECHANISMS

Importance in advancing the field.

Understanding the risk shifting capacity of the different contracting mechanisms available to the Corps would be valuable to construction finance, and to the government, in helping to develop strategies for financing, valuing, and accomplishing risky projects. Specifically, if quantified, the value of risk shifting in these instances could be programmed back into the valuation mechanism and appropriate contracting forms could be more efficiently chosen to match the risk and the parties' abilities to bear it. In the arena of technological innovation on remediation projects, the record has been poor. Principle in this is a lack of understanding, especially by Field Operating Agencies (FOAs) of the Corps, of the magnitude of risk associated with project-specific contracting mechanisms. There is a general understanding that conventional contracting mechanisms are adversarial and self-serving, and alternative contracts can result in shorter performance periods, reduced contract costs, and improved quality. However, quantifying this and distilling it into a decision calculus for developing contracting strategies is lacking. With risk itself as a barrier to entry into this industry, especially for smaller firms championing new technologies, such an understanding is most important. Additionally, pursuing such a research topic would help to develop project BETAs for environmental remediation jobs using different contract mechanisms.

Analytical framework and formal plan.

The research plan would first identify the remediation projects now being pursued by the Corps and the contracting mechanisms used on each. I think we would want to investigate why these contract forms were chosen, specifically, whether it was organizational inertia or precedent ("that's what we know and can do without thinking too much about it"), dictated by regulation or statute, and whether it was a conscious decision of the Contracting Officer. It would be important to develop a "spread" of contract types, forming a large enough representative sample, so some comparisons could be drawn between them. However, if only a few contracts were let by the Corps or if all were of the same form, the investigation would necessarily broaden to EPA work and projects in private industry or at the state and local level. The next step would be to try and group projects by risk category and size to compare the contract dollar amounts across the several contract types. With the fixed-price / competitive bid model as our baseline or control, we could develop risk premiums for each project and, correspondingly, contract type. From this, knowing 1) the prevailing risk free rate, either nationally or regionally, 2) something about how the contractor had leveraged the project, and 3) something about the portfolio of projects of that firm, or firms similar to it, conclusions about the BETA for the specific project could be developed. This could be extrapolated back to the type of project and contract form used, establishing a base of data (BETAs) for such jobs. This database could be subsequently used by the Corps to develop risk allocation strategies for remediation projects. Such a program would help Contracting Officers in developing programs for equitably allocating the environmental, financial, and operating risks of remediation jobs by assisting them in matching the right contract form to the type of job and contractor.

SOPHISTICATED VALUATION METHODS

Importance in advancing the field.

The procedure normally employed by the Corps in valuing construction contracts comes directly from manuals and handbooks which outline the best estimated costs for specific construction activities. Once an estimated construction cost (ECC) is developed, a percentage for profit and overhead are added, normally 15% total, and an overall project value is developed. No project-specific consideration is given to the financial values of time, money, or risk. Consequently, the value of the project to the contractor is overstated and the costs to the government understated, from a long term, life cycle perspective. At bid openings, contract award is based upon the lowest quoted bid. If the government could value projects, and bids, using VC or an Option Model, we would better understand the premiums construction contractors place on flexibility and uncertainty, along with the risks associated with specific project types.

Analytical framework and formal plan.

There are thousands of construction contracts let by the Corps each year. They range significantly in contract amount, scope, and risk. Of these contracts, the overwhelming predominance are fixed-price / competitive bid, as already discussed. Emphasis on "cookbook valuation" loses sight of the longer term value of jobs as well as the value to contractors of leaving options open (flexibility).

A research program in this area would be directed at determining the dollar amount by which the government is overpaying, or underpaying, its contractors each year, strictly from a financial analytical point of view. Understanding that there are significant subsidies paid by the government to firms for political reasons, the analysis would hope to establish the difference between how the government values and pays for services vis a vis how more sophisticated valuation models say they should.

A number of contracts would be selected, grouped by region, risk (degree of difficulty), dollar amount, and period (year and month, so as to consider the periodic variations in construction cycles). By group, each contract, along with the bid abstract (listing the competing contractors and their bids), would be evaluated. The spread of bids on any given job would reveal a number of things, such as, the contractor's need for work at the time of bid opening, the risk associated with the quality of plans and specifications, actual constructability risk, and how contractors view the risks of dealing with the government. Using a regression analysis technique, Contracting Officers could establish individual risk premiums by type of jobs, type of contract, and for their commands in general. This information could be used as a mechanism for future cost programming, where the government could direct resources to reducing those sources of risk, as viewed by the contractors. For the Corps' role in IRP and waste minimization, a more sophisticated approach must be investigated.

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